TYPES OF STRUCTURES
&LOADS

Introduction

There are many different types of structures all around us. Each structure has a specific purpose or function. Some structures are simple, while others are complex; however there are two basic principles of composing structures:

- They must be capable of carrying the loads that they are designed for without collapsing, and
- They must support the various parts of the external load in the correct relative position.

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- They must support the various parts of the external load in the correct relative position.

A structure refers to a system with connected parts used to support a load (e.g. buildings, bridges, towers, ship, aircraft frames, tanks, pressure vessels, mechanicals systems, electrical supporting structures). However, these structures are very complex to analyze and design.

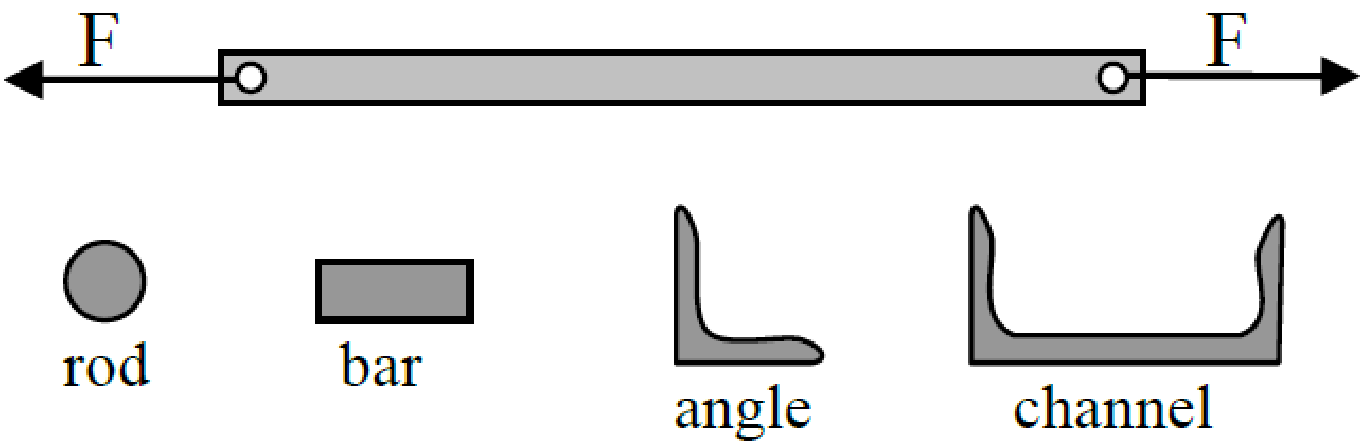
Introduction

At first, we will consider simple examples of structures and parts of structures like beams, trusses, frames, etc. When designing a structure to serve a specified function for public use, the engineer must account for its safety, esthetics, and serviceability, while taking into consideration economic and environmental constraints. It is important for a structural engineer to recognize the various types of elements composing a structure and to be able to classify them as to there form and function. We will introduce some of these aspects.

Structural Elements

Tie Rods

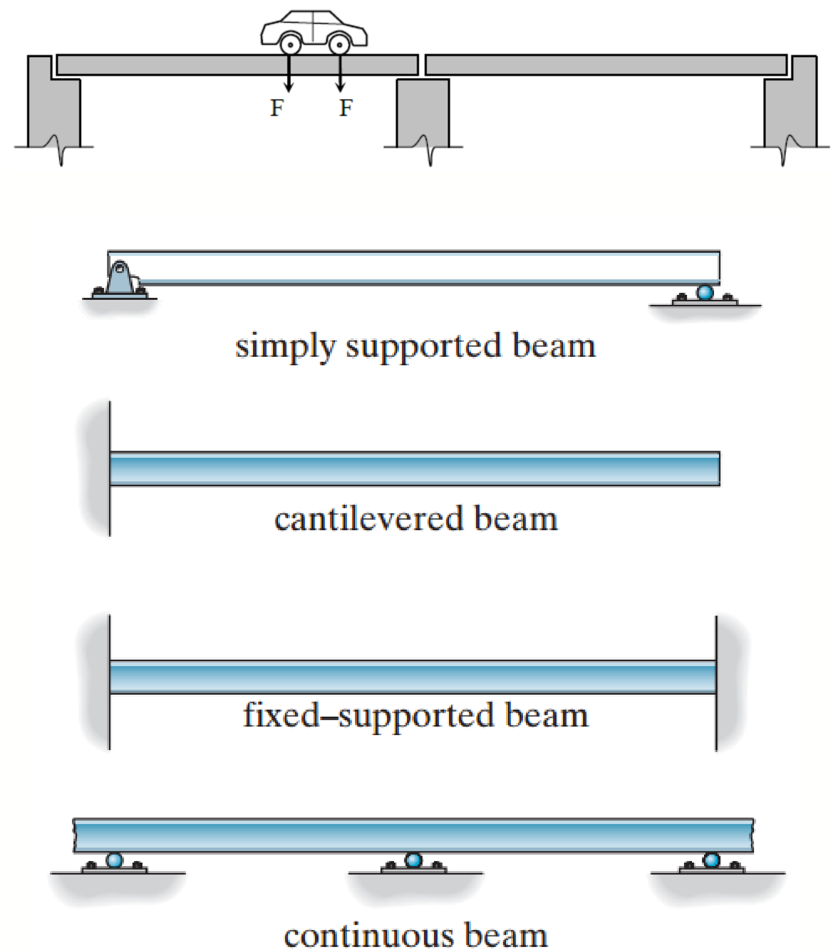
- Structural members subjected to a tensile force. Due to the nature of the load, these elements are rather slender and are often chosen from rods, bars, angles, or channels.



Structural Elements

Beams

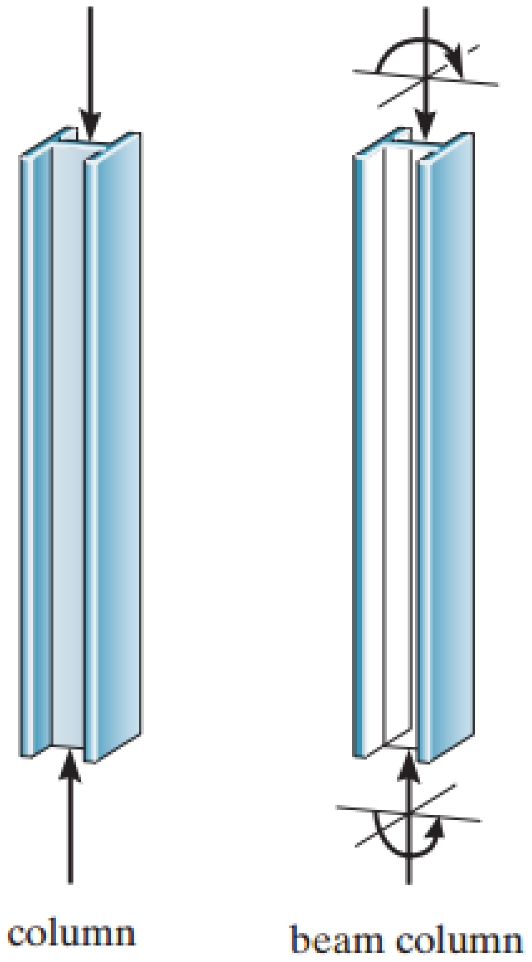
- Straight horizontal members used primarily to carry vertical loads, and primarily designed to resist bending moment, however, if they are short and carry large loads, the internal shear force may become quite large and this force may govern their design. Beams may be designed from several elements and materials (e.g. concrete, metal, timber) with rectangular or other cross sections.



Structural Elements

Columns

- Members that are generally vertical and resist axial compressive loads. Occasionally, columns are subjected to both an axial load and bending moment.

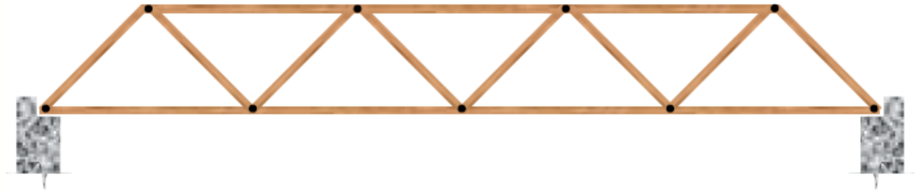


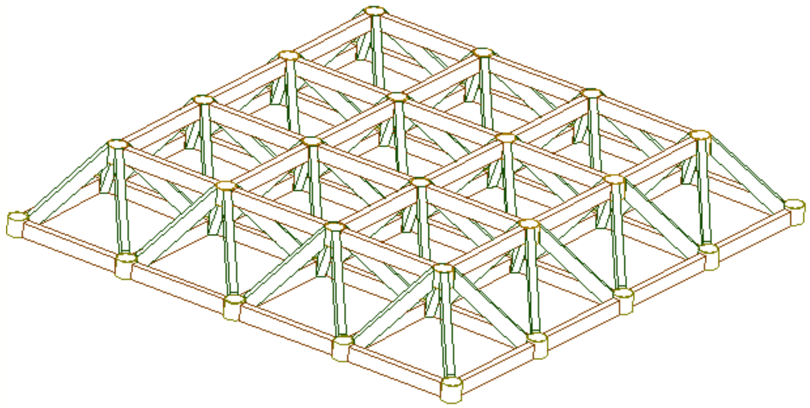
The combination of structural elements and the materials from which they are composed is referred to as a structural system. Each system is constructed of one or more of four basic types of structures.

Types of Structures

Trusses

- They are composed of slender rods usually arranged in triangular fashion. Trusses are suitable for constructions with large span when the depth is not important criterion for design. Planar trusses are composed of members that lie in the same plane and are frequently used for bridge and roof support, where as space trusses have members extending in three dimensions and are suitable for derricks and towers.





Types of Structures

Cables and Arches

- Other forms of structures used to span long distances.
- Cables are usually flexible and carry their loads in tension, and commonly used to support bridges.
- The arch achieves its strength in compression, since it has a reverse curvature to that of the cable, and frequently used in bridge structures, dome roofs, etc.

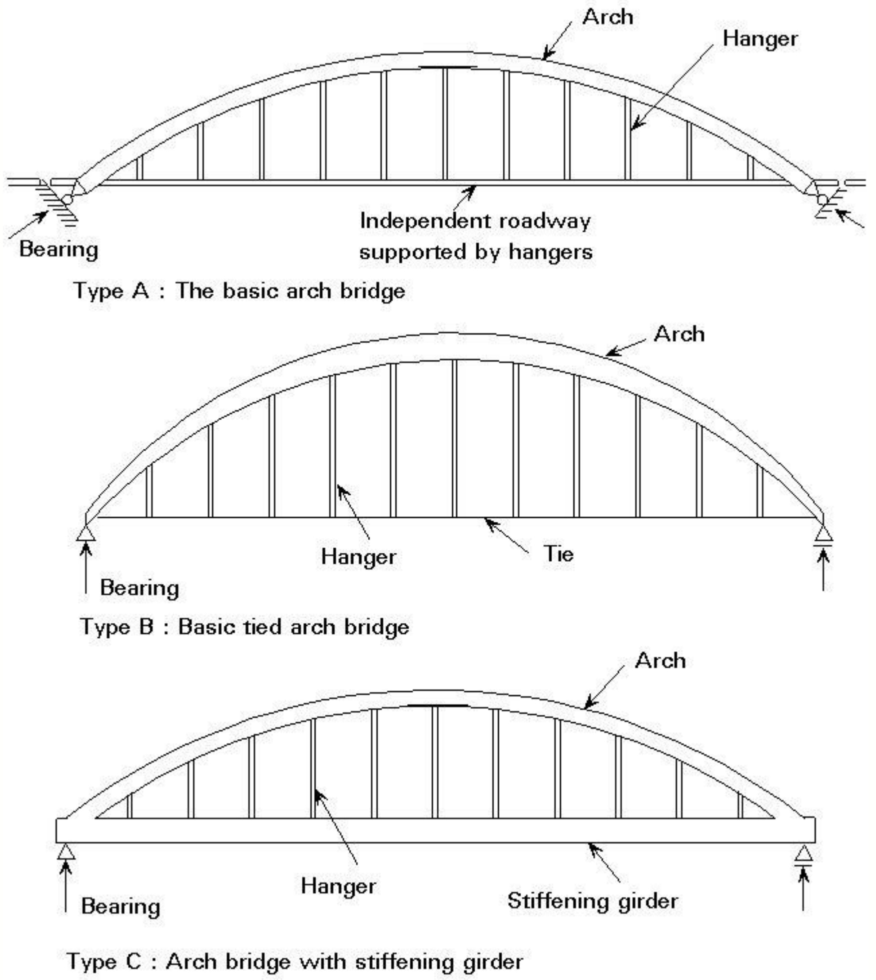
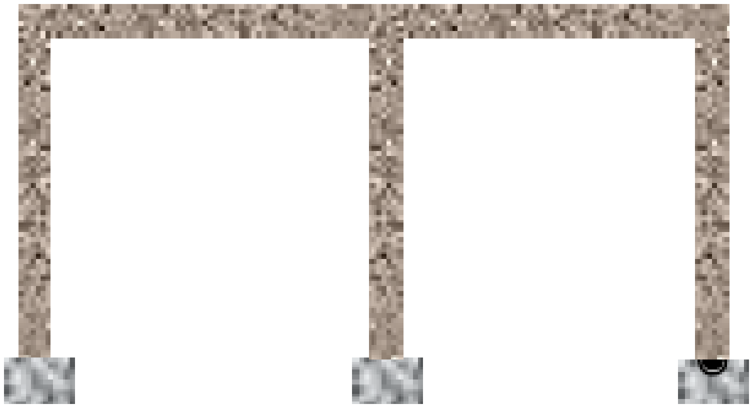


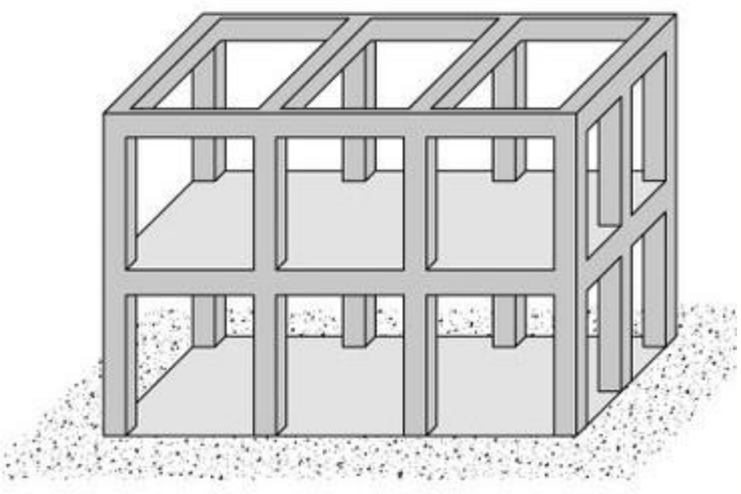
Figure 1 Types of arch bridge

Types of Structures

Frames

- They are often used in buildings and are composed of beams and columns which are with hinge or rigid connections. These structures are usually indeterminate and the load causes generally bending of its members.

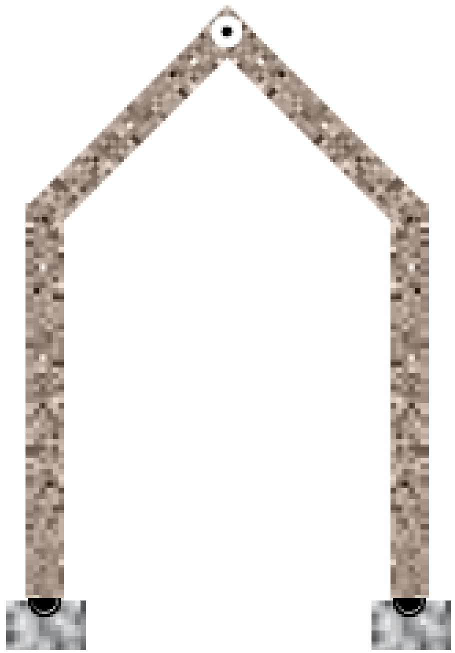


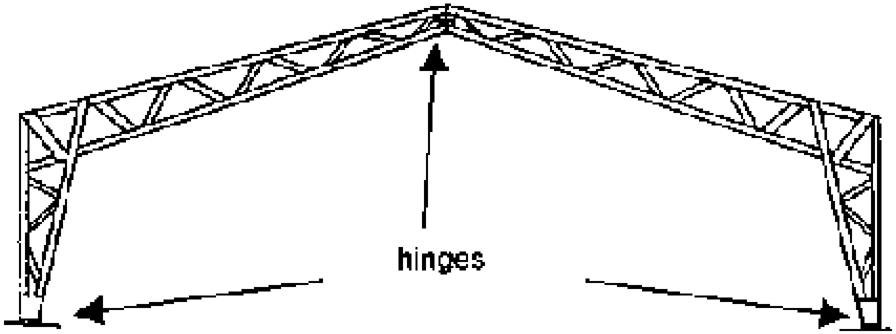


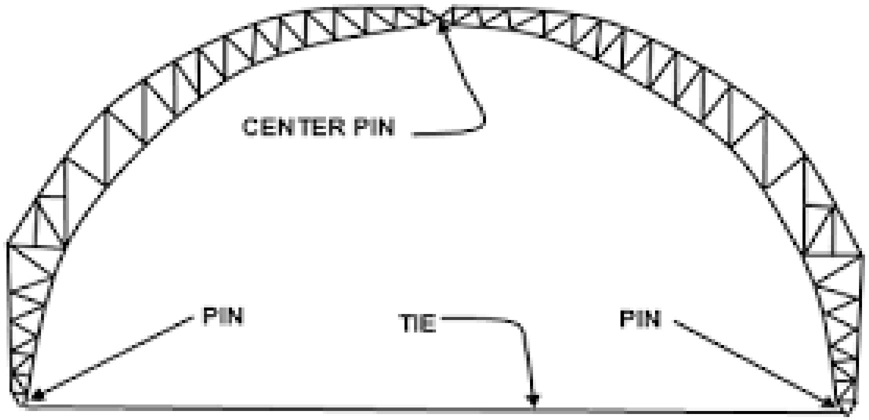
Types of Structures

Three-hinged Frame

- This structure is simple determinate frame used generally for base element for complicated frame structures.







Types of Structures

Surface structures

- They are made from a material having a very small thickness compared to its other dimensions. These structures can be made from flexible or rigid material and can take the form of a tent or air-inflated structure (flexible) and may be shaped as folded plates, cylinders, or hyperbolic paraboloids, and are referred to as thin plates or shells (rigid).

Loads

Important Codes used in Practice

TABLE 1–1 Codes

General Building Codes
Minimum Design Loads for Buildings and Other Structures, ASCE/SEI 7-10, American Society of Civil Engineers
International Building Code
Design Codes
Building Code Requirements for Reinforced Concrete, Am. Conc. Inst. (ACI)
Manual of Steel Construction, American Institute of Steel Construction (AISC)
Standard Specifications for Highway Bridges, American Association of State Highway and Transportation Officials (AASHTO)
National Design Specification for Wood Construction, American Forest and Paper Association (AFPA)
Manual for Railway Engineering, American Railway Engineering Association (AREA)

Loads

Dead Loads

▪Consists of the weights of the various structural members and the weights of any objects that are permanently attached to the structure. Hence, for a building, the dead loads include the weights of the columns, beams, and girders, the floor slab, roofing, walls, windows, plumbing, electrical fixtures, and other miscellaneous attachments.

TABLE 1–2 Minimum Densities for Design Loads from Materials*

	lb/ft^3	kN/m^3
Aluminum	170	26.7
Concrete, plain cinder	108	17.0
Concrete, plain stone	144	22.6
Concrete, reinforced cinder	111	17.4
Concrete, reinforced stone	150	23.6
Clay, dry	63	9.9
Clay, damp	110	17.3
Sand and gravel, dry, loose	100	15.7
Sand and gravel, wet	120	18.9
Masonry, lightweight solid concrete	105	16.5
Masonry, normal weight	135	21.2
Plywood	36	5.7
Steel, cold-drawn	492	77.3
Wood, Douglas Fir	34	5.3
Wood, Southern Pine	37	5.8
Wood, spruce	29	4.5

*Reproduced with permission from American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*, ASCE/SEI 7-10. Copies of this standard may be purchased from ASCE at www.pubs.asce.org.

TABLE 1–3 Minimum Design Dead Loads*

Walls	psf	kN/m^2
4-in. (102 mm) clay brick	39	1.87
8-in. (203 mm) clay brick	79	3.78
12-in. (305 mm) clay brick	115	5.51
Frame Partitions and Walls		
Exterior stud walls with brick veneer	48	2.30
Windows, glass, frame and sash	8	0.38
Wood studs 2 × 4 in., (51 × 102 mm) unplastered	4	0.19
Wood studs 2 × 4 in., (51 × 102 mm) plastered one side	12	0.57
Wood studs 2 × 4 in., (51 × 102 mm) plastered two sides	20	0.96
Floor Fill		
Cinder concrete, per inch (mm)	9	0.017
Lightweight concrete, plain, per inch (mm)	8	0.015
Stone concrete, per inch (mm)	12	0.023
Ceilings		
Acoustical fiberboard	1	0.05
Plaster on tile or concrete	5	0.24
Suspended metal lath and gypsum plaster	10	0.48
Asphalt shingles	2	0.10
Fiberboard, $\frac{1}{2}$-in. (13 mm)	0.75	0.04

*Reproduced with permission from American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*, ASCE/SEI 7-10.

Loads

Live Loads

- Live loads can vary both in their magnitude and location. They may be caused by the weights of objects temporarily placed on a structure, moving vehicles, or natural forces.

Building Loads

The floors of buildings are assumed to be subjected to uniform live loads, which depend on the purpose for which the building is designed.

TABLE 1–4 Minimum Live Loads*

Occupancy or Use	Live Load psf	Live Load kN/m^2	Occupancy or Use	Live Load psf	Live Load kN/m^2
Assembly areas and theaters			Residential		
Fixed seats	60	2.87	Dwellings (one- and two-family)	40	1.92
Movable seats	100	4.79	Hotels and multifamily houses		
Garages (passenger cars only)	50	2.40	Private rooms and corridors	40	1.92
Office buildings			Public rooms and corridors	100	4.79
Lobbies	100	4.79	Schools		
Offices	50	2.40	Classrooms	40	1.92
Storage warehouse			Corridors above first floor	80	3.83
Light	125	6.00			
Heavy	250	11.97			

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Loads

Highway Bridge Loads

The primary live loads on bridge spans are those due to traffic, and the heaviest vehicle loading encountered is that caused by a series of trucks.

Railroad Bridge Loads

Train loadings involve a complicated series of concentrated forces, hence, tables and graphs are sometimes used in conjunction with influence lines to obtain the critical load.

Impact Loads

Moving vehicles may bounce or sidesway as they move over a bridge, and therefore they impart an impact to the deck.

Wind Loads

When structures block the flow of wind, the wind's kinetic energy is converted into potential energy of pressure, which causes wind loading.

Loads

Snow Loads

In some parts of the country, roof loading due to snow can be quite severe, and therefore protection against possible failure is of primary concern.

Earthquake Loads

Earthquakes produce loadings on a structure through its interaction with the ground and its response characteristics.

Hydrostatic and Soil Pressure

When structures are used to retain water, soil, or granular materials, the pressure developed by these loadings becomes an important criterion for their design.

Other Natural Loads

These include the effects of blast, temperature changes, and differential settlement of the foundation.

Loads

Problem Set 1

1. The floor of a heavy storage warehouse building is made of 6-in thick stone concrete. If the floor is a slab having a length of 15 ft and width of 10 ft, determine the resultant force caused by the dead load and the live load.

Loads

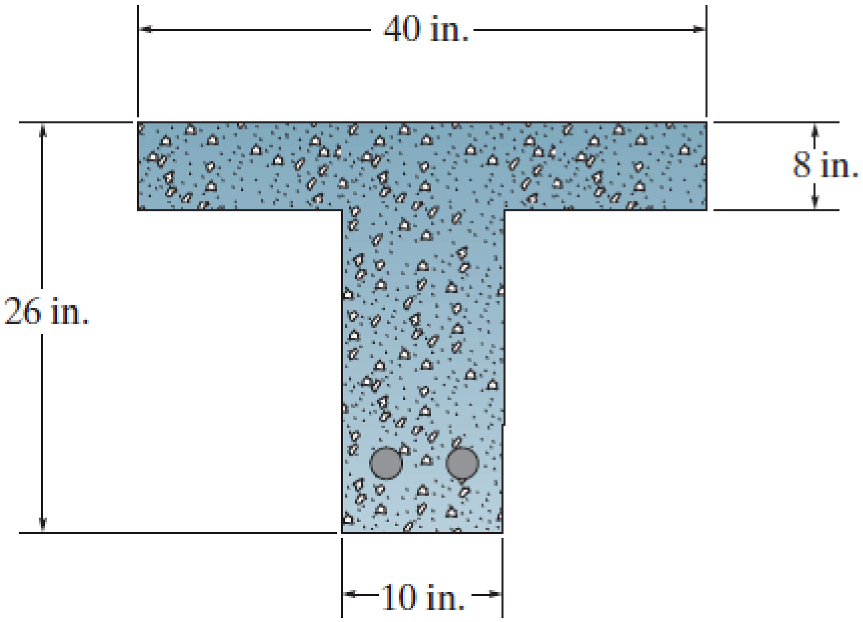
Problem Set 1

2. The floor of the office building is made of 4-in thick lightweight concrete. If the office floor is a slab having a length of 20 ft and width of 15 ft, determine the resultant force caused by the dead load and the live load.

Loads

Problem Set 1

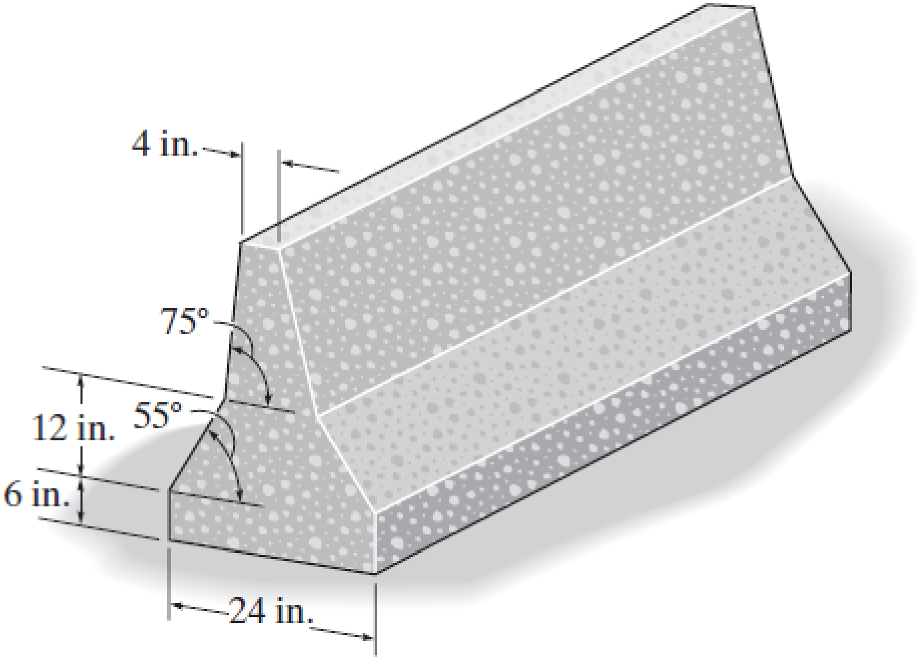
3. The T-beam is made from concrete having a specific weight of 150 lb/ft^3. Determine the dead load per foot length of beam. Neglect the weight of the steel reinforcement.



Loads

Problem Set 1

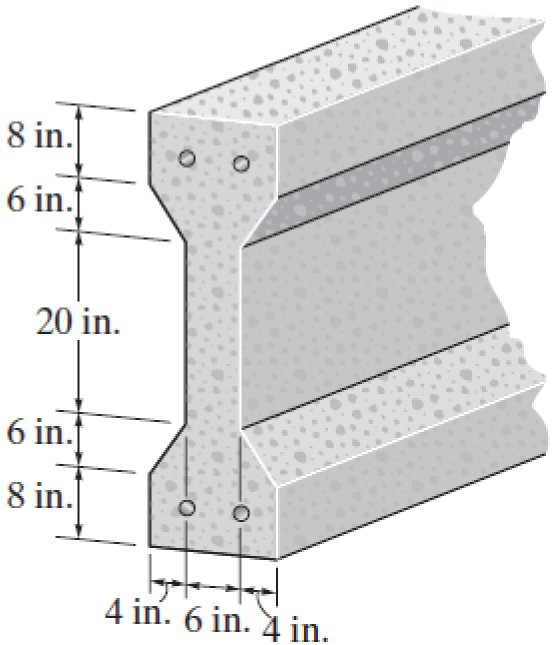
4. The “New Jersey” barrier is commonly used during highway construction. Determine its weight per foot of length if it is made from plain stone concrete.



Loads

Problem Set 1

5. The prestressed concrete girder is made from plain stone concrete and four ¾ in cold-form steel reinforcing rods. Determine the dead weight of the girder per foot of its length.



Structural Design

ASD

- Allowable-stress design (ASD) methods include both the material and load uncertainties into a single factor of safety.
  - dead load
  - 0.6 (dead load) + 0.6 (wind load)
  - 0.6 (dead load) + 0.7 (earthquake load)

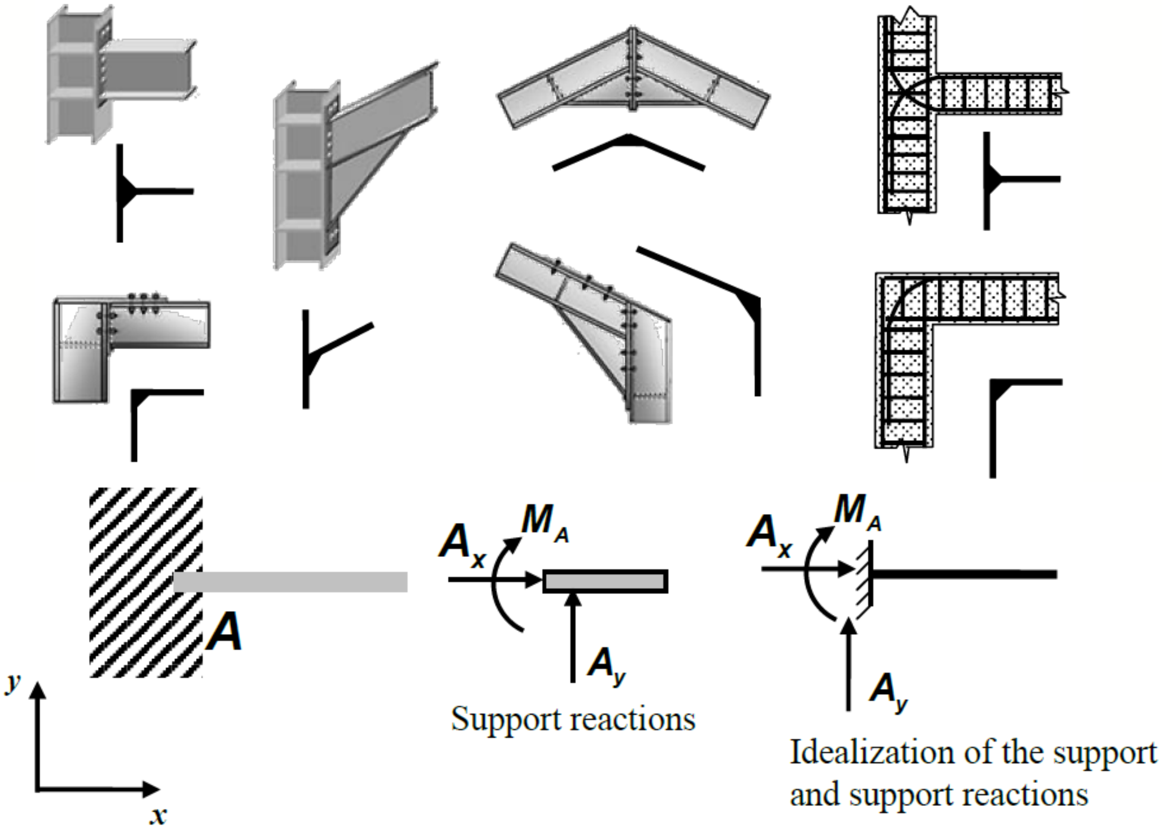
LRFD

- Since uncertainty can be considered using probability theory, there has been an increasing trend to separate material uncertainty from load uncertainty. This method is called strength design or LRFD (load and resistance factor design).
  - 1.4 (dead load)
  - 1.2 (dead load) + 1.6 (live load) + 0.5 (snow load)
  - 0.9 (dead load) + 1.0 (wind load)
  - 0.9 (dead load) + 1.0 (earthquake load)

Idealized Structures

Rigid (Fixed) Support

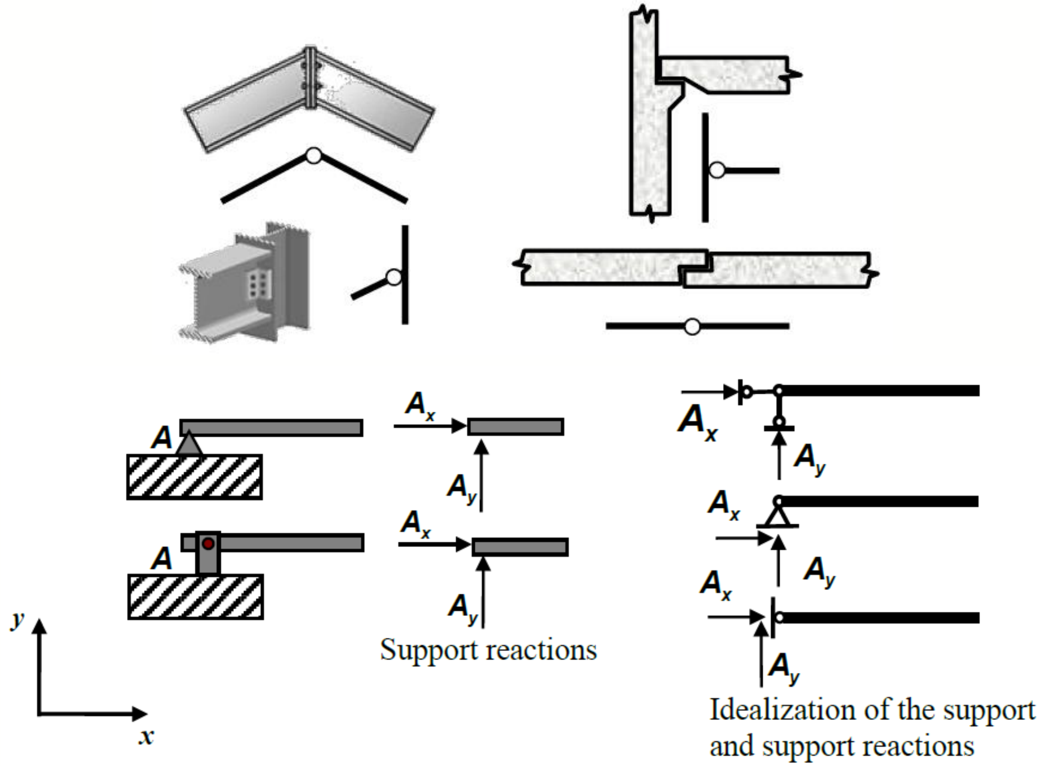
- This support carry moment, shear and axial forces between different members. This kind of support doesn't allow any nodal rotations and displacements of the support point.



Idealized Structures

Hinged (Pin) Support

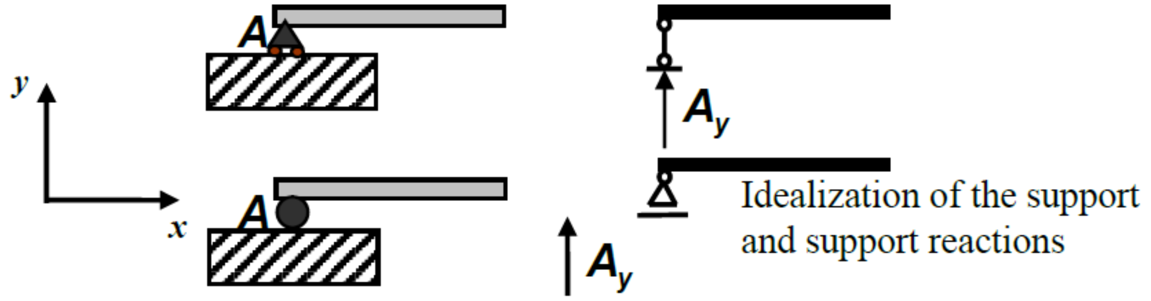
- This support carry shear and axial forces but not moment between different members. The hinged support allows rotation of the support point but the two displacement are equal to zero.



Idealized Structures

Roller Support

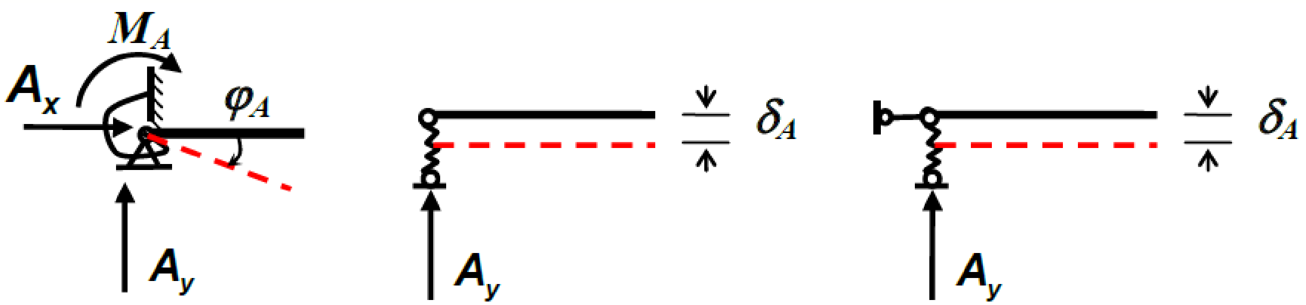
- This support carry only shear forces between jointed members. The roller support allows rotation and one displacement of the support point.



Idealized Structures

Spring Supports

▪These supports are like the previous but with the difference that they are not ideally rigid but with some real stiffness. The spring has a stiffness constant c equals to the force caused by displacement d = 1.



Fixed spring support $M_A = c.\ \varphi_A$

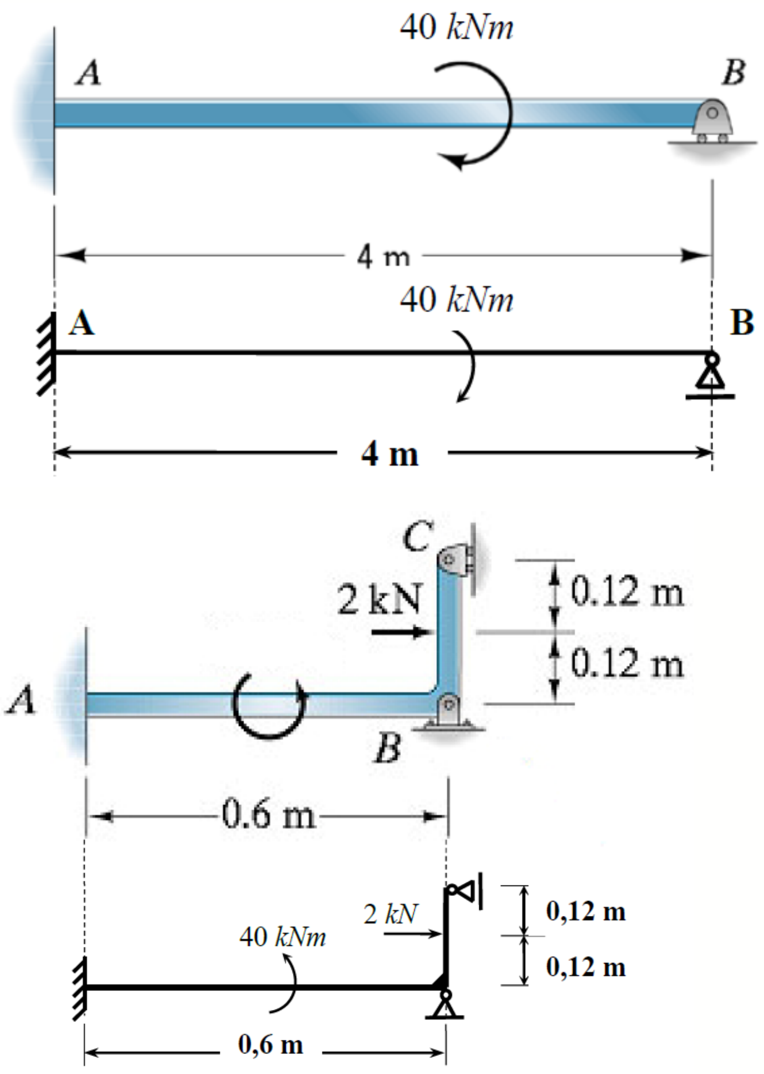
Roller spring support $A_y = c.\ \delta_A$

Pin (hinged) spring support $A_y = c.\ \delta_A$

Idealized Structures

Structure Idealization

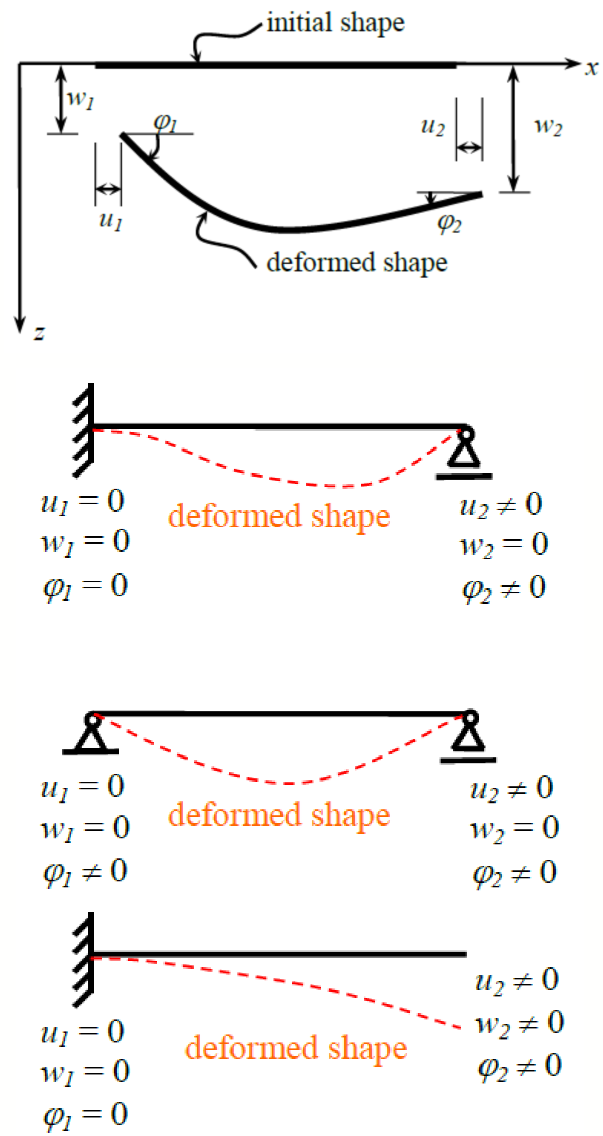
- The main idea of this idealization is to made a mathematical model of the real construction to be convenient for analysis and calculation. After we know the idealization of different joints and supports, we will take care about whole structure idealization. To make this we follow the middle axis of the elements of the structure. In the following figure are shown some real and idealized structures:



Principles and Preconditions

Displacements

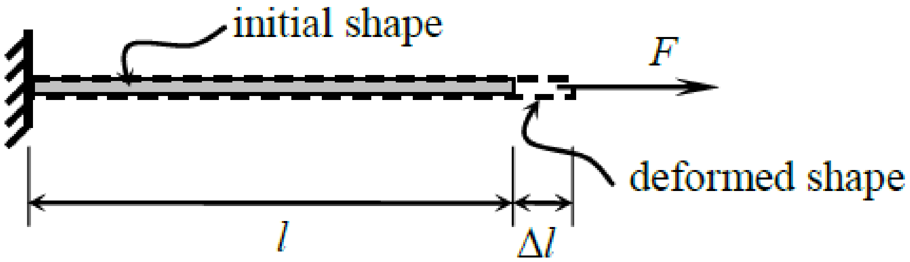
- Every two dimensional deformable element has three degrees of freedom (two displacements and one rotation) of each its end node. With using different support links, we control these degrees of freedom so the elements cannot move on the limited direction or it moves with controlled value. These limitations are called boundary conditions. On the following figure are shown the degrees of freedom and some boundary conditions for elements:



Principles and Preconditions

Deformation

- Deformation or strain is the change in the metric properties of a continuous body (element) caused by some load. A change in the metric properties means that the element changes its length and shape when displaced to a curve in the final position – the deformed shape.

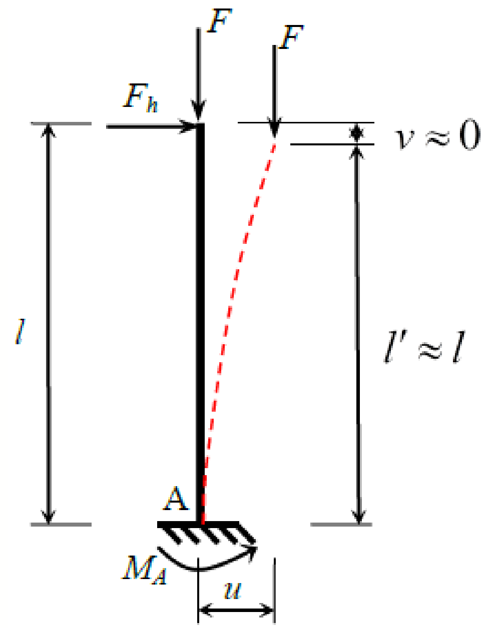


$$\varepsilon = \frac{\Delta l}{l} \text{ – elongation (deformation) of the element}$$

Principles and Preconditions

Preconditions about displacements and deformations

We presume that the displacements are small according to the dimensions of the element and deformations are small according to the unit. These preconditions allow us to write equilibrium conditions for the initial shape of the structure and also to neglect the small displacement of the structure.



Equilibrium condition for deformed shape:

$$\sum M_A = o : M_A = F.u + F_h.(l - v)$$

Equilibrium condition for deformed shape if $v \approx 0$:

$$\sum M_A = o : M_A = F.u + F_h.l$$

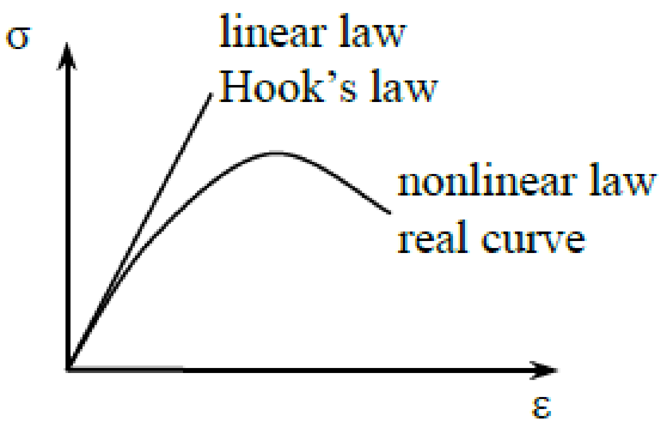
Equilibrium condition for the initial shape and $v \approx 0$ (small displacement and small deformations):

$$\sum M_A = o : M_A = F_h.l$$

Principles and Preconditions

Precondition about the material

We suppose that the connection between stress and strain is linear so the Hook's law is valid. This is acceptable because of presumption of small deformation.

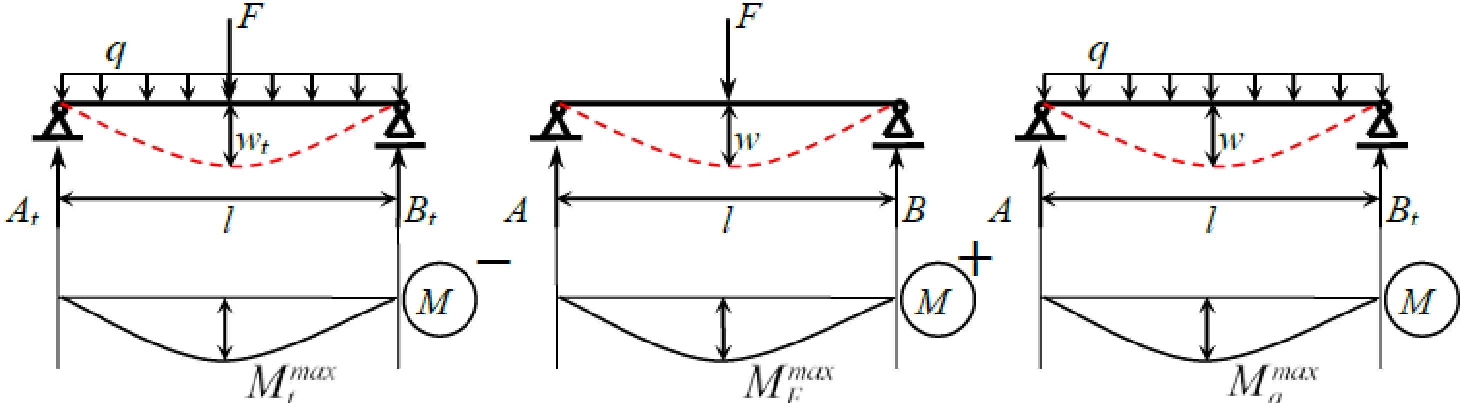


$$\sigma = E.\varepsilon - \text{Hook's law}$$

Principles and Preconditions

Principle of superposition

The previous two preconditions allow us to use the principle of superposition. It may be stated as follow: The total displacement or internal forces at a point in a structure subjected to several external loadings can be determined by adding together the displacements or internal forces caused by each of the external loads acting separately.



$$A_t = A_F + A_q; \quad B_t = B_F + B_q; \quad w_t = w_F + w_q$$

$$M_t = M_F + M_q; \; M_t^{max} = M_F^{max} + M_q^{max}$$